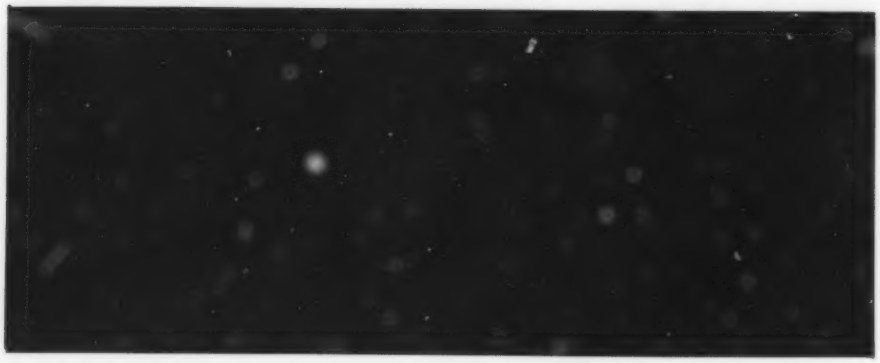
ADF

Saskatchewan Agriculture
Development Fund



Keeping the agriculture and food industries competitive through Research, Development and Demonstration.

92-06717/

Final Report

R-86-05-0172

Breeding for Resistance to Leaf Rust in Durum Wheat

Funded by
The Agriculture Development Fund
January 29, 1991

Final Report
ADF Contract R-86-05-0172

Breeding for Resistance to Leaf Rust in Durum Wheat

D.R. Knott

A. EXECUTIVE SUMMARY

1. Abstract

In 1986 there was a tremendous buildup of leaf and stem rust in the great plains of North America. Although resistant wheat varieties limited the damage on the Canadian Prairies (except for winter wheat), several durum wheats showed only partial resistance to leaf rust. Since almost nothing is known about leaf rust resistance in durum wheat, a project was begun to identify the genes for resistance in a set of nine varieties, seven of which have been grown in Canada and the northern U.S.A., and in potential parents for durum breeding. The main purpose of the research was to provide information and to develop leaf rust resistant parents for use by durum wheat breeders. Somewhat surprisingly all of the first set of varieties proved to carry different genes for leaf rust resistance. Durum wheat evidently carries a large pool of genes for leaf rust resistance.

2. Summary

The tremendous buildup of stem and leaf rust of wheat in the great plains of North America in 1986 demonstrated the potential for rust epidemics that still exists. Except for some winter wheat fields, only limited damage occurred because of the resistance carried by Canadian bread and durum wheats. However, several commercial durum varieties showed only moderate resistance to leaf rust. This raised concern that possibly new races of leaf rust were developing that could attack current durum varieties.

Very little work has been done anywhere in the world on leaf rust resistance in durum wheat. In North America, leaf rust on durum wheat has been considered to be of minor importance because most varieties have resistance. However, this could change rapidly if it happens that most varieties depend on the same genes for resistance. For this reason, a project was begun to study the inheritance of leaf rust resistance in a number of durum wheat varieties. Studies were done both in the field and in the greenhouse. The objectives were to provide information and germplasm that would be valuable to durum wheat breeders.

Initially, nine durum wheat varieties were selected for study — Medora, Wakooma, Stewart 63, Pelissier, Golden Ball, Lloyd, Vic, Quilafen (Chile), and PI 192179 (Ethiopia). They were chosen to represent old and new durum varieties in North America, plus two from other areas. PI 192179 proved to have little resistance and was dropped. All possible crosses (28) were made among the remaining eight varieties to see if they carried the same genes for resistance. Plants from the second generation of each cross were tested with leaf rust in the greenhouse. All 28 crosses segregated susceptible plants, showing that all of the varieties had different genes for resistance. This was somewhat surprising, particularly since Pelissier is a parent of Wakooma. Some of the most resistant plants from crosses between two resistant parents were selected in order to combine genes from both. Their progeny were tested in the field to see if they were more resistant than the parents. Unfortunately, leaf rust developed very poorly even in irrigated field nurseries in 1988, and only moderately in 1989. The rust epidemic was good in 1990 but all but one of

the parents was essentially immune so it was impossible to select lines more resistant than their parents.

Each of the eight parents was crossed to a susceptible durum, RL 6089, and the eight hybrids were crossed again (backcrossed) to RL 6089. Fifty families from each backcross except one were tested in the greenhouse to determine the inheritance of resistance in each parent. The backcross seeds for Vic failed to germinate and the backcross is being repeated. The tests showed that Golden Ball, Lloyd, Pelissier, Quilafen and Wakooma each had one gene and Medora and Stewart 63 each had two, for a total of nine different genes. Lines carrying each of these genes separately were isolated and tested with six different leaf rust races in order to determine the degree of resistance controlled by each gene and the range of races to which it gave resistance. The genes from Pelissier and Golden Ball gave good resistance to all six races while the gene from Wakooma was weak and gave resistance to only one race. The other three genes gave varying levels of resistance to four or five races.

Some of the backcross families were also tested in a field leaf rust nursery. Each gene that gave resistance in seedlings in the greenhouse was also effective in adult plants in the field. In addition, Lloyd and Pelissier were each found to carry a gene that had no effect in seedlings but provided resistance in adult plants in the field.

When it was discovered that the first eight resistant parents all had different genes for resistance, it was decided to test some additional commercial cultivars, Arcola, Coulter, Kyle, Sceptre and Wascana. Nine crosses involving these varieties were made and all segregated susceptible plants in the second generation. Thus, in every case the parents carried different genes for resistance. The results show clearly that durum varieties carry a large number of different genes for leaf rust resistance.

Since it was thought that new sources of leaf rust resistance might be needed by durum wheat breeders, 177 durum varieties from international sources were tested for resistance. Thirty-eight were selected and crossed and backcrossed to RL 6089, the susceptible parent. Preliminary data have been obtained but testing is not yet complete. The lines almost certainly contain additional genes not identified in the previous sets of parents.

As a result of the studies, durum wheat breeders have considerably more information about the inheritance of leaf rust resistance in durum wheat. Lines carrying specific genes with known reactions to six leaf rust races are available. Some particularly resistant gene combinations have been selected for use in breeding work. Since 1986, the weather has been generally unfavorable for the development of rusts and they have not caused any new threats, although a new race of stem rust that is virulent on most barley varieties has now appeared.

B. TECHNICAL REPORT

1. Abstract

The inheritance of leaf rust resistance was studied in eight durum varieties, Medora, Wakooma, Stewart 63, Pelissier, Golden Ball, Lloyd, Vic, Quilafen (Chile) and PI 192179 (Ethiopia). All 28 diallel crosses among the eight parents segregated for resistance showing that the parents each carried different genes for resistance. Genetic analysis of backcrosses to a susceptible line, RL 6089, showed that Golden Ball, Lloyd, Pelissier, Quilafen and Wakooma each carry one gene, and Medora and Stewart 63 each carry two.

Each of the nine genes was isolated in a homozygous line and tested with six leaf rust races. The line carrying the gene from Quilafen gave reactions similar to a line of Thatcher carrying resistance gene *Lr 17* and a line carrying one of the genes from Stewart 63 gave reactions similar to line of Thatcher carrying *Lr 16*. Crosses have been made to determine if Quilafen and Stewart 63 do carry *Lr 17* and *Lr 16* respectively.

Attempts were made to combine genes from some of the parents. These are incomplete because of various problems with field rust nurseries, particularly in 1988.

Five additional commercial varieties, Arcola, Coulter, Kyle, Sceptre and Wascana were selected and nine crosses involving them were made. These nine crosses also segregated for leaf rust resistance, further indicating the substantial number of resistance genes carried in durum wheat.

To broaden the sources of resistance, thirty-eight durum varieties from other countries were selected. They have been crossed and backcrossed to a susceptible parent but the tests have not yet been completed.

2. Background and Objectives

Durum wheat breeders in the Canadian prairies and North Dakota routinely select for leaf rust resistance and release only resistant varieties. Almost all varieties used as parents have resistance and, although crosses may segregate susceptible plants, it is easy to eliminate them during the development of new varieties.

In the summer of 1986, a tremendous load of leaf rust spores blew in from the United States. Although all commercial durum cultivars had some resistance, several, including Wascana, showed enough rust development to cause at least some rust damage. This raised concern as to whether the leaf rust races were changing and posed a future threat to durum production. Since 1986, leaf rust in central north America has not again built up sufficiently during the summer to be a serious threat to wheat production in Canada.

A review of the literature revealed that almost nothing is known about the inheritance of rust resistance in durum wheat. If durum wheat breeders are to breed intelligently for resistance to leaf rust, they must have information about the genes for resistance carried by current varieties and by potential parents. The objectives of this project were:

(a) To determine the genes for leaf rust resistance carried by some of the commercial durum varieties grown in Saskatchewan.

(b) To identify some new sources of resistance.

(c) To produce good combinations of genes for rust resistance for use in durum breeding programs.

3. Experimental Methods

Initially, nine varieties that were either grown commercially or had been used as parents in breeding programs were selected for study — Stewart 63, Wakooma, Medora, Pelissier, Golden Ball, Lloyd, Vic, Quilafen (Chile) and PI 192179 (Ethiopia). The latter proved to have little leaf rust resistance and was dropped. The remaining eight varieties were intercrossed in all combinations (28 crosses) and were crossed with a leaf rust susceptible line RL 6089 (8 crosses). The F_1 plants from the crosses with RL 6089 were

backcrossed to RL 6089 for studies on the inheritance of resistance. The backcrosses were also used to isolate individual resistance genes in a fairly uniform genetic background.

When results were obtained on the initial set of varieties, five additional commercial varieties, Arcola, Coulter, Kyle, Sceptre and Wascana, were selected and nine crosses involving them and some of the first set of varieties were made.

To obtain some idea of the resistance carried by international durum varieties, 177 entries were tested with race 15 of leaf rust. Ninety-three of the more resistant entries were selected and 38 were crossed and backcrossed to RL 6089, the susceptible parent.

As appropriate, parents and various crosses and backcrosses were tested with race 15 of leaf rust in seedling tests in the greenhouse. Five additional races of leaf rust were used in some cases.

Some material was also tested each summer in artificially inoculated rust nurseries. In some cases race 15 alone was used and in some cases a multirace mixture. The purpose was to determine whether genes that controlled seedling resistance also produced adult plant resistance, and also to see if there were additional genes that resulted in resistance only in adult plants but not in seedlings. Field infection with rust is seriously affected by hot, dry weather. In 1988, even though the nurseries are irrigated, no useful results were obtained. In 1989, the results were better but still not good. In 1989, the field rust nurseries gave excellent results. However, not as much was accomplished as hoped because of the poor results in 1988 and 1989.

4. Results and Discussion

(a) Crosses Among Resistant Parents.

When F_2 populations from the 28 crosses involving the first eight resistant parents were tested at the seedling stage with race 15 of leaf rust, all of the crosses segregated susceptible plants. This showed that all eight parents carry different genes for leaf rust resistance, a result that was somewhat unexpected. For example, Pelissier is a parent of Wakooma and it was thought that they might have a gene in common but they did not.

Five additional varieties were selected and nine crosses involving them were made as follows: Arcola/Wascana, Coulter/Medora, Coulter/Sceptre, Coulter/Wakooma, Kyle /Wakooma, Kyle/Medora, Sceptre/Lloyd, Wascana/Pelissier and Wascana/Wakooma. All nine crosses segregated plants susceptible to race 15 of leaf rust, indicating that the parents of each cross do not have genes in common. The data further demonstrate the large number of genes for leaf rust resistance that are present in durum wheat. The fact that Wascana and Wakooma did not have a gene in common was surprising, since both come from the same backcross, Pelissier/2* Lakota.

In 1989, F2 populations from 21 of the 28 crosses among the first eight resistant parents were grown in a field rust nursery. Plants that appeared to be more resistant than either of their parents were selected. In 1990, F_3 families from the selected F2 plants were tested in a multirace field nursery. It was expected that the parents would be only partially resistant to the mixture and that plants could be selected that were more resistant than either parent. These plants would then combine genes for resistance from both parents and could be valuable in durum breeding work. Unfortunately, all of the parents except Wakooma proved to be essentially immune to the mixture. While this indicated that current leaf rust races pose little threat to durum wheat, it also made it impossible to select for gene combinations.

(b) Genetic Studies on Seven of the First Eight Resistant Parents.

Fifty F_2 families from each backcross of a resistant parent to RL 6089, except for Vic, were tested with race 15 in the seedling stage in the greenhouse. The backcrosses involving Vic failed to germinate and have been remade but tests are not yet complete. The results showed that two of the parents each carry two genes and the other five each carry one, for a total of nine genes (Table 1). Based solely on an F_2 population (not a backcross), Vic carries either 1 or 2 additional genes.

Table 1. Genes for leaf rust resistance carried by the seven resistant parents. The genes are labelled *Lr* plus two letters from the name of the parent.

Variety	Genes for resistance
Golden Ball	*Lr GB*
Lloyd	*Lr Ld*
Medora	*Lr Md 1, Lr Md 2*
Pelissier	*Lr P1*
Quilafen	*Lr 17?*
Stewart 63	*Lr St, Lr 16?*
Wakooma	*Lr Wk*

Resistant plants from some of the backcross families were selfed and homozygous resistant lines obtained. At least one line was obtained for each of the nine identified genes. These nine lines were then tested at the seedling stage with six races of leaf rust. The parents and 19 lines of Thatcher wheat each carrying a leaf rust gene that could be present in durum wheat (i.e. on an A or B genome chromosome) were also tested (Table 2). The resistant line derived from Quilafen gave similar reactions to the Thatcher line carrying *Lr 17* (resistant to five races but susceptible to race 161). The two lines are being crossed to determine whether Quilafen does carry *Lr 17*. Although the line derived from Quilafen is susceptible to race 161, Quilafen is resistant. This shows that Quilafen carries another gene that gives resistance to race 161 but not to race 15, the race used in the genetic studies. One of the two lines derived from Stewart 63 gave similar reactions to the Thatcher line carrying *Lr 16* (resistant to five races but moderately susceptible to race 100). A cross has been made to determine if the line carries *Lr 16*.

Some of the backcross families from six of the resistant parents (not including Golden Ball) were tested in the field to determine whether families that segregated for resistance in the seedling stage also had resistance in the field, and also whether families that were susceptible as seedlings segregated for resistance in the field. In all cases, genes that controlled seedling resistance also controlled adult plant resistance (this is almost always the case with genes for rust resistance). A number of the backcross families derived from Lloyd and from Pelissier were susceptible at the seedling stage but segregated for resistance in the field. This indicates that Lloyd and Pelissier each carry a gene that is effective in adult plants but not in seedlings.

Table 2. Reaction of 7 parents, 9 lines derived from them and 2 Thatcher lines to 6 races of leaf rust. Rust readings are on a 0-4 scale with 0 being immune, 1 resistant, 2 moderately resistant, 3 moderately susceptible and 4 susceptible. A ; indicates yellow flecks.

Parent or line	Leaf rust race					
	1	15	58	100	104	161
Golden Ball	1=	1	1	1	1+	1
Golden Ball/2*RL 6089-21	1	1	2	;1	;1+	1+
Lloyd	;1+	1	1	3-	;1	1
Lloyd/2*RL 6089-4	1-	1+	2	3-	1+	1
Medora	1+	1-	1	3-	;1-	1
Medora/2*RL 6089-31	1	2	2-	3-	1-	1+
Medora/2*RL 6089-32	1-	2	1+	3	2	2-
Pelissier	1=	1	1	1+	;1=	1
Pelissier/2*RL 6089-10	1=	1=	;1-	;1=	;1=	1=
Quilafen	1=	1-	1+	1-	;1	1-
Quilafen/2*RL 6089-4	1+	1	1	;1=	;	3+
Thatcher-*Lr 17*	;1	1	;1	;1=	;1=	4
Stewart 63	1=	1=	1=	;1	;1=	1=
Stewart 63/2*RL 6089-3	1-	1+	1	3-	;1=	1=
Stewart 63/2*RL 6089-22	2	2+	3	;1	1-	2
Thatcher - *Lr 16*	1-	1	2	3	1+	1
Wakooma	1	2+3-	4	4	3+	2+
Wakooma/2*RL 6089-8	2	3	4	4-	3+	4

(c) Genetic Studies on Selected International Varieties.

International durum varieties will almost certainly carry genes for leaf rust resistance that have not been used in Canadian varieties. Thirty-eight varieties with good resistance were selected and crossed and backcrossed to the susceptible parent, RL 6089. Testing of some of the backcrosses has been done but it has not been completed as yet because of a shortage of greenhouse space. The tests will be completed as space becomes available. When lines homozygous for individual genes have been obtained, they will be tested with the six leaf rust races to try and determine if the genes are different than those already identified.

5. Conclusions and Impact

The result s obtained were somewhat surprising in that no two varieties tested so far have been found to carry a gene in common. Since some varieties are related by parentage, it was expected that they would have genes in common. In particular, Wascana and Wakooma are derived from the same cross of which Pelissier is one parent. Nevertheless, the three do not have a resistant gene in common.

The results demonstrate that durum wheat provides a large reservoir of genes for leaf rust resistance, a number of which have been identified. Leaf rust is more of a problem in bread wheat. Some of the resistant genes in durum wheat provide a good level of resistance to all six races of leaf rust they were tested against (notably the genes from Golden Ball and Pelissier) and should be useful in bread wheat. However, the transfer of resistance from durum to bread wheat is often difficult or impossible. A separate project to attempt to transfer resistance from five durum varieties to bread wheat has been started.

In three years substantial progress has been made in an area in which very little was known before. The main objective outlined in the application, the identification of genes for leaf rust resistance in eight varieties of durum wheat has been completed. Both the information and the lines produced are available to other durum wheat breeders. A request for the single gene lines was received from the U.S.D.A. Cereal Rust Laboratory, University of Minnesota, St. Paul, Minn. and seed was sent.

Partly because of the problems with field rust nurseries in 1988 and 1989, and partly because the threat of leaf rust seems to have diminished since 1986, not much has been accomplished in transferring particularly good combinations of resistant genes into commercial varieties. However, all material in the durum breeding program is screened for leaf rust resistance both during the early segregating generations and again when uniform lines have been produced and are in yield test.

C. PAPERS AND TALKS

A paper will appear in the November-December issue of Crop Science as follows:

Zhang, H. and D.R. Knott. 1990. Inheritance of leaf rust resistance in durum wheat. Crop Science 30:

Hongtao Zhang used the research for his M.Sc. thesis.

Zhang, H. 1990. The inheritance of leaf rust resistance in durum wheat. M.Sc. thesis, University of Saskatchewan. 75 pp.

D.R. Knott gave a preliminary report on the work at the Cereal Rust Workshop in Winnipeg, April 11-13, 1989. this meeting included most of the key rust workers from the north-central U.S.A. and the Canadian prairies and made them aware of the program being carried out at the University of Saskatchewan and the material available.

D. EXPENDITURES

A statement will be sent separately from Research Accounts.

E. PERSONNEL AND TIME INVOLVED

D.R. Knott - 5%, but substantially more since June 1990.

Hongtao Zhang - 75% until June 1990 when he graduated and obtained a job at the Lethbridge Research Station.

Two technicians provided occasional assistance with field and greenhouse work as required, particularly after Zhang left.

F. EQUIPMENT

No item of equipment with a value in excess of $500 was purchased.